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The Effect of a Prophylactic Knee Brace on Muscle Performance

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THE EFFECT OF A PROPHYLACTIC KNEE BRACE ON MUSCLE PERFORMANCE

by

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An Abstract

of a thesis submitted in partial fulfillment
of the requirements for the degree of
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ABSTRACT

This study investigated the effect of a prophylactic knee brace on muscle performance as described by lactate concentration difference, maximal anaerobic power, peak torque, rise time, and time to fatigue. The subjects were 25 male football players between the ages of 18 and 23 years from Ithaca College and Cornell University. Each subject performed two tests on a Cybex dynamometer and the Wingate cycle test, one trial with a brace and another trial without a brace, with the order of the brace condition assigned randomly. In addition, pretest and posttest blood samples were obtained during both trials for lactate analysis. MANOVA revealed no significant difference ($p > .05$) in overall performance between brace and no brace conditions. A 2 x 2 factorial MANOVA demonstrated that subjects' familiarity with a brace and their order of brace and no brace testing during Trial 1 and Trial 2 did not influence overall performance. In addition, a 2 x 2 factorial MANOVA showed no indication of a trial effect on the combined performance variables. However, a univariate ANOVA on maximal anaerobic power demonstrated a significant ($p < .05$) trial effect. Tukey's (a) test further revealed that Order 1 subjects significantly increased their maximal anaerobic power scores from Trial 1 to Trial 2, whereas Order 2 subjects did not. A possible learning effect on the Wingate cycle test coupled with a negative brace effect on maximal anaerobic power may explain this result, even though

for the combined performance variables neither a significant trial effect nor a significant brace effect was evident.

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A Thesis Presented to the Faculty of
the School of Health, Physical
Education, and Recreation
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In Partial Fulfillment of the
Requirements for the Degree
Master of Science

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by
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December 1987

Ithaca College
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Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Cindi Aileen Gold

submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College has been approved.

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Chapter 1

INTRODUCTION

Inherent in athletics, especially contact sports, is the potential for injury. The knee joint, by nature of its structure, is one of the most vulnerable joints for injury (Knutzen, Bates, & Hamill, 1984). Trauma to the knee or surrounding structures can create a functional loss or alter the mechanics of the joint. External support is often needed to prevent injured ligaments from further injury or to protect surgically repaired ligaments from reinjury (Anderson, Zeman, & Rosenfeld, 1979). Knee braces were originally designed for this purpose, but have evolved for use as prophylactic devices during athletic participation (Ryan, 1986).

The Sports Medicine Committee of the American Academy of Orthopaedic Surgeons (1984) has classified the rapidly increasing number and types of braces into three categories: prophylactic, rehabilitative, and functional. Prophylactic braces are designed to prevent or reduce the severity of knee injuries, rehabilitative braces are designed to allow protected motion of an injured knee treated operatively or nonoperatively, and functional braces are designed to provide stability for unstable knee joints.

Thousands of professional and collegiate athletes wear prophylactic braces for the promise of knee injury prevention, but the effectiveness of these braces in preventing injuries is a controversial topic (Potera, 1985). An important concern in athletics, other than the mechanical stability offered by prophylactic braces, is the effect these braces have on athletic performance. This study was designed to provide information about the effect of a prophylactic knee brace on selected parameters of muscle performance.

Scope of Problem

This study examined the effect of a Stromgren prophylactic knee brace on selected parameters of muscle performance: peak torque, rise time, and time to fatigue measured on a Cybex II isokinetic dynamometer, maximal anaerobic power estimated during a Wingate cycle test, and lactate concentration difference. Subjects were 25 male college football players with healthy knees recruited from Ithaca College and Cornell University. The subjects were asked to report twice to the Ithaca College Physical Therapy Electrophysiology Laboratory for testing. Subjects who expressed familiarity with a brace were noted.

Each subject was tested with a brace during one trial and without a brace during another trial according to random assignment. On each visit, the subjects performed two tests on a Cybex dynamometer and a test of maximal anaerobic power on a cycle ergometer. In addition, resting and postexercise blood samples were taken. MANOVA was performed to examine if a statistically significant difference in lactate concentration, maximal anaerobic power, peak torque, rise time, and time to fatigue existed between brace and no brace conditions.

Statement of Problem

The effect of wearing a Stromgren prophylactic knee brace on selected parameters of muscle performance, as measured by a Cybex II isokinetic dynamometer, the Wingate anaerobic test, and lactate concentration difference in male college football players, was investigated.

Null Hypotheses

A Stromgren prophylactic knee brace has no effect on selected parameters of muscle performance in male college football players. Additionally, three subhypotheses were stated. First, subjects' familiarity with a knee brace has no effect on their performances. Second, there is no order effect (i.e., there is no difference in performance scores that can be attributed to whether the brace was worn on the first trial or the second trial). Third, there is no difference in subjects' performances that can be attributed just to trials (i.e., no learning effect from Trial 1 to Trial 2), especially on maximal anaerobic power.

Assumptions of Study

The following were assumptions of this study:

1. The tests used were accurate measures of muscle performance.

2. All subjects were equally motivated to perform maximally during brace and no brace trials.

Definitions of Terms

The following terms were operationally defined for the purpose of this study:

1. Healthy Knee: A knee that has not undergone surgery, has not suffered a severe injury within 2 years prior to testing or a mild injury within 5 months prior to testing, and does not suffer from any chronic ailments.

2. Peak torque: The highest quadriceps torque (in foot pounds) during eight maximal flexion and extension contractions at 60 deg/s.

3. Rise time: The time in seconds from the beginning of the first knee extension to peak torque at 60 deg/s.

4. Time to fatigue: The time in seconds from peak quadriceps torque to half of peak torque at 120 deg/s.

5. Maximal anaerobic power: The maximal rate of work production (in watts) at the expense of ATP and creatine phosphate breakdown.

6. Lactate concentration difference: The difference (in millimoles) between pretest and posttest blood lactate concentrations.

7. Familiarity with a brace: Required brace use by athletes during a competitive season.

Delimitations of Study

The following delimitations were appropriate for this study:

1. Male college football players (N = 25) between the ages of 18 and 23 years were used as subjects in this study.

2. Only college football players with healthy knees were chosen as subjects.

3. A Monark cycle ergometer and a Cybex II dynamometer were used for testing.

4. A Stromgren knee brace was worn for the brace condition of testing.

5. Peak torque, rise time, time to fatigue, maximal anaerobic power, and lactate concentration difference were used as measures of muscle performance.

Limitations of Study

The following limitations existed for this study:

1. Wearing a knee brace may have had a psychological effect as well as a physical effect on the athletes' performances.

2. Results only apply to college football players with healthy knees.

3. Results only apply when a Cybex II dynamometer, a Monark cycle ergometer, and a Stromgren knee brace are used for testing.

4. Results only apply when peak torque, rise time, time to fatigue, maximal anaerobic power, and lactate concentration difference are used as measures of muscle performance.

Chapter 2

REVIEW OF LITERATURE

This chapter presents literature concerning the structure of prophylactic knee braces, the effectiveness of prophylactic braces on knee injury prevention, and the effect these braces have on athletic performance.

Structure of Prophylactic Braces

Two general types of prophylactic braces are available. One type of brace consists of lateral bars with single axis, dual axis, or polycentric hinges fitted with hyperextension stops. The other type of brace consists of plastic cuffs with polycentric hinges that can be custom fitted (American Academy of Orthopaedic Surgeons, 1984). These braces are typically applied bilaterally, and attachment to the leg is by tape, straps, or elastic wraps.

Effectiveness of Prophylactic Braces

The purpose of prophylactic braces is to prevent or reduce the severity of knee injuries from contact and noncontact stresses. Biomechanical and clinical research have been conducted to attempt to substantiate this effect.

Biomechanical Evidence

Manufacturers claim that prophylactic braces protect against contact loading and protect against valgus stress and medial collateral ligament (MCL) injury by dispersing an impact load away from the knee joint. Some brace manufacturers also claim to provide lateral, rotational, and anterior/posterior stability as well (American Academy of

Orthopaedic Surgeons, 1984). These claims are based upon limited research, and data to substantiate these effects are either limited or not available.

Four prophylactic braces were demonstrated by Daniel (cited in Potera, 1985) to have no effect on anterior displacement when braced knees were subjected to a 20-lb Lachman test, an active anterior drawer test, or a manual maximum Lachman test. In fact, fresh taping was found to be superior to all of the braces tested in limiting anterior displacement to the 20-lb Lachman test.

Static bench testing was performed to determine joint displacement and knee stiffness of cadaver knees with and without prophylactic braces (Paulos, Drawbert, France, & Rosenberg, 1986). Quasi-static nondestructive loading at three flexion angles and high rate ligament failure loading at 30° flexion were performed under idealized conditions. The initial tests showed an increase in valgus force was necessary to open the braced knee joint. However, the MCL loads were also greatly increased. Paulos et al. (1986) argued that the only way both these events can occur simultaneously is if the ligament is preloaded or stressed by the brace itself. Joint opening force and ligament tension measurements failed to show any significant benefit from the braces in nonpreloaded knees tested to failure.

Biomechanical studies have also been conducted utilizing rehabilitative and functional braces. It is important to briefly discuss these types of braces because athletes are commonly returned to participation wearing rehabilitative and functional braces for the purpose of preventing reinjury in addition to providing restricted motion or mechanical stability for unstable knee joints.

Manufacturers claim that rehabilitative and functional braces control motion about the knee that is detrimental to healing ligaments and cartilage. However, documented research in this area is contradictory and, therefore, inconclusive (American Academy of Orthopaedic Surgeons, 1984).

The ability of six rehabilitative knee braces to stabilize ligamentous injuries of the knee was evaluated using fresh cadavers (Hofmann, Wyatt, Bourne, & Daniels, 1984). Anterior, valgus, and rotational forces were applied to the intact knee, after the anterior cruciate ligament (ACL) and MCL ligaments were severed, and after brace application. Results showed that all of the braces provided increased stability compared to unbraced knees with severed ligaments. However, when compared with intact knees, the majority of braces did not duplicate natural ligamentous stability.

Biomechanical studies have reported that functional braces are effective in limiting anterior/posterior knee motion under very low force conditions. However, these braces were not found to control or restore knee laxity to normal under high force related to athletic activity in sports (American Academy of Orthopaedic Surgeons, 1984).

Clinical Evidence

Clinical evidence of the effectiveness of prophylactic braces consists of evaluations of injury records of football players from universities and professional teams. Studies have shown reduced knee injury rates, no difference in injury rates, and increased injury rates with prophylactic brace use compared to no brace use during similar periods of time.

Studies from Notre Dame, the University of Iowa, and Iowa State University demonstrated a trend toward reduced incidence of serious MCL injuries requiring surgery while prophylactic braces were worn. However, none of these studies documented a statistically significant reduction of these injuries (American Academy of Orthopaedic Surgeons, 1984).

Medical records of football players at the University of Southern California were reviewed, and the number and type of injuries and knee surgeries during a 4-year period were recorded, noting which players wore prophylactic braces and which did not (Hansen, Ward, & Diehl, 1985). Results showed an 11% injury rate in 329 players who did not wear braces and a 5% injury rate in 148 players who did wear braces.

Another study that suggested that prophylactic braces are effective in reducing or preventing knee injuries reviewed injury records of professional football players (Anderson et al., 1979). Players who sustained previous knee injuries (N = 9) were followed for periods ranging from one to six games, during which time prophylactic braces were worn. The records showed that none of the nine players sustained reinjury while wearing the prophylactic braces. Although this study suggests that prophylactic brace use may prevent reinjury, the results were not statistically significant, and the longitudinal nature of the investigation is limited.

Several studies have shown no significant difference in injury rates with brace use. Taft, Hunter, and Funderburk (cited in Paulos et al., 1986) statistically analyzed all knee injuries that occurred at the University of North Carolina at Chapel Hill 5 years before and 2 years after prophylactic braces began to be used. The results showed no change in the total number of MCL or ACL injuries. However, there was a 70% decrease in surgically treated MCL injuries, so the authors concluded that lateral braces may reduce the number of severe MCL knee injuries. This study was criticized for using surgical treatment as an indication of the severity of injuries (Paulos et al., 1986).

A comparison of 4 years of unbraced to 4 years of braced knee injuries at the University of Arizona (Hewson, Mendini, & Wang, 1986) showed no statistically significant difference in the number or severity of knee injuries between the braced and unbraced periods. A similar finding was demonstrated at the University of Oregon (cited in American Academy of Orthopaedic Surgeons, 1984). A review of injury records over a 3-year period reported no beneficial effect in reduction of incidence or severity of MCL injuries from prophylactic brace use.

Contrary to the desired effect of brace use, incidence rates of knee injuries were higher when prophylactic braces were worn for 2 years than they were during a similar period when braces were not worn at Wake Forest University (Rovere, Haupt, & Yates, 1987). A larger number of ACL injuries was noted during the brace period than during the no brace period.

A clinical case encountered at the University of North Carolina (cited in American Academy of Orthopaedic Surgeons, 1984) suggests that an injury sustained by a football player wearing a prophylactic brace was worse than what would have been sustained if the player had not been wearing a brace. The player received an anterior lateral blow resulting in a severe hyperextension injury with damage to posterior structures. It was suggested that the brace prevented valgus deformity and as a result converted the injury into a more severe injury. This concern is theoretically sound, but no significant adverse effects have been substantiated (American Academy of Orthopaedic Surgeons, 1984).

The reports of increased incidence of injury from prophylactic brace use raise the issue of preloading. Preloading is the condition which results when prophylactic braces, which are designed with 5° of physiologic valgus alignment, are applied to a neutrally or varus aligned knee.

Investigators claim that the MCL and cruciate ligaments are stressed as the knee is pushed into the brace, thus, increasing an athlete's susceptibility to injury (American Academy of Orthopaedic Surgeons, 1984; Paulos et al., 1986).

In summary, data reported from clinical studies are difficult to interpret because of the contradictory findings. Other changes that have occurred in football (e.g., several new rule changes introduced within the last 5 years, changes in coaching technique, the use of artificial turf, alterations in footwear, and the naturally occurring fluctuations in incidence of injury from year to year), along with the use of prophylactic braces, could account for the reported changes in knee injury rate and severity of injury (American Academy of Orthopaedic Surgeons, 1984).

Effect of Brace Use on Performance

An important concern in athletics, other than the efficacy of prophylactic braces as an injury-preventing device, is the effect these braces have on athletic performance. Research is limited in this area, and many studies examining athletic performance in relation to brace use have utilized functional braces. Results have shown facilitated performance, impaired performance, and no difference in athletic performance with brace use.

Skilled athletes, two of whom had no history of knee injury and six who had had some type of surgical repair, were observed to move and accelerate faster during a straight run when wearing a functional brace than when not wearing a brace (Groppel & Shin, n.d.). All except one of the subjects were also able to change direction with less deceleration occurring just prior to a cutting maneuver. Groppel and Shin explained that it was difficult to conclude whether these results were purely physical due to increased support from the brace, or psychological, or a combination of both.

Quadriceps muscle peak strength was analyzed using a Cybex II isokinetic dynamometer in subjects (N = 24) with patellofemoral arthralgia (Lysholm, Nordin, Ekstrand, & Gillquist, 1984). The results showed that 88% of the subjects improved their performances in a strength test with application of a patella brace. Although these results and those of Groppel and Shin (n.d.) suggest facilitated performance with brace application, it should be emphasized that the improvements shown were in subjects who had diagnosed knee problems (arthralgia and/or instability). Generalization of these results to an athletic population in which prophylactic braces are typically applied to healthy knees should be made with caution.

In contrast to the reports of facilitated performance with brace use, several investigations have indicated negative effects. The effect of a functional brace and an elastic support brace on tibial rotation and torque of the surgically repaired knee was evaluated by Knutzen, Bates, and Hamill (1984). Comparisons were also made with the healthy contralateral limb. Results indicated a consistent trend of both knee brace applications to create a decrease in external rotation and torque components of the surgically repaired knee.

The influence of two functional knee braces on knee joint movements and ground reaction forces during running was assessed electrogoniometrically by Knutzen, Bates, Schot, and Hamill (1987). Results showed that both knee brace applications significantly reduced knee flexion during swing and support, total rotation, and total varus/valgus movement of the injured knee during running. Results also showed changes in ground reaction forces as a result of brace application. The brace conditions were shown to produce greater impact forces coupled with a time delay in the achievement of maximum impact force. Knutzen et al. (1987) reported that this alteration in force generation has previously been shown to be associated with changes in running speed.

The effect of wearing a functional brace on energy expenditure during horizontal treadmill running was evaluated by Zetterlund, Serfass, and Hunter (1986). It was observed that running with a brace required a significantly higher energy expenditure than running without a brace. Young adult males with ruptured ACL exhibited a 4.58% increase in oxygen consumption and a 5.10% increase in heart rate when wearing a knee brace at the identical work load.

Houston and Goemans (1982) evaluated leg muscle performance characteristics of male athletes (<u>N</u> = 7) with and without their prescribed functional braces. Subjects' testing order and sequence of brace and no brace trials were randomized. No significant difference in isometric contraction torque values on a Cybex dynamometer was found between conditions. However, peak torque values during dynamic contractions were significantly lower when subjects wore braces. This difference became larger with increased velocity. Results also revealed that wearing knee braces increased blood lactate concentration by 41% during a 15-min ergometer ride at a fixed load. Houston and Goemans suggested that because lactate levels were markedly higher when braces were worn, despite the identical workloads, braces could interfere with blood flow and thus, oxygen delivery. In addition, performance on a brief all-out stair run was slower ($\underline{p}$ < .01) with brace application. In spite of the subjects' familiarity with their braces, performance measures on all the dynamic leg tests were poorer during the brace condition.

Similar findings to those of Houston and Goemans (1982) utilizing a prophylactic brace have been reported by Chen (1987). Peak torque, rise time, and time to fatigue values of dynamic contractions on a Cybex dynamometer by female college lacrosse players ($\underline{N}$ = 10) free of knee injury were examined with and without a brace. Measures of peak anaerobic power recorded from performance on the Wingate anaerobic test and blood lactate concentration were also examined. Results revealed that overall performance was significantly impaired under the brace condition ($p < .05$) compared to the no brace condition.

Hansen (1981) reported findings contrary to those of Houston and Goemans (1982) and Chen (1987). Football players ($N = 12$) representing various positions and free of knee injury performed three trials of tests for strength, endurance, and power on a Cybex dynamometer. A prophylactic brace was worn unilaterally during one of the trials. Data from the two trials performed without a brace were compared to determine if a learning effect occurred as a result of repetitive testing. Results showed no significant difference ($p > .05$) in the physical parameters measured with and without brace application and no indication of a learning effect.

Similar findings regarding maximum torque production on a Cybex dynamometer were reported by Clover (cited in Prentice & Toriscelli, 1986). A prophylactic brace worn bilaterally resulted in no significant difference in maximum torque, forward running speed, and agility with and without brace application.

Several studies conducted at Indiana State University examining the effects of a prophylactic brace worn unilaterally on agility and forward running speed indicated similar findings. Johnson (1969) examined the ability of graduate students ($N = 14$) to perform a 40-yd agility run with and without brace application. Results indicated no significant difference ($p > .05$) in agility. A similar study by Martindale (1973) utilizing male physical education students (N = 20) also showed no significant difference in agility with and without brace use.

Hawkins (1977) examined the effect of a prophylactic brace on forward running speed. Male and female physical education students (N = 17) performed two timed 30-yd sprints with and without a brace. Results indicated no significant effect ($p > .05$) of brace use on running speed.

Prentice and Toriscelli (1986) reported results that conflict with those of Clover (cited in Prentice & Toriscelli, 1986) and Hawkins (1977) regarding forward running speed. Male college students (N = 20) performed a 40-yd forward sprint, a 20-yd backward sprint, and an agility drill using directional changes and cariocas, all at maximum speed with three different prophylactic braces and without a brace. Results indicated that all three braces significantly decreased forward running speed relative to speed without a brace. Speeds during backward sprinting and during the agility run were not affected by brace application.

Drawbacks of knee braces other than impaired performance and the possibility of preloading have been suggested. Rovere et al. (1987) reported muscle cramping in the triceps surae in college football players, probably secondary to tight wrapping of the brace around the lower leg. In addition, high costs are sustained to outfit a football team when the cost of the brace, personnel time in assisting in brace application, and wrapping supplies are considered. Player acceptance and skin problems due to anchorage of the brace to the skin are also drawbacks (American Academy of Orthopaedic Surgeons, 1984).

Summary

There are currently two general types of prophylactic braces available. Thousands of college and professional athletes are wearing these braces for the purpose of knee injury prevention, but the effectiveness of these braces in preventing injuries has not been conclusively substantiated. Biomechanical and clinical studies have shown increases, decreases, and no change in injury rates and severity of injury with brace use.

Studies that report increased injury rates due to brace use suggest that preloading is responsible and may cause more severe injuries than injuries that occur without brace use. Clinical reports of decreased injury rates in response to brace application are difficult to evaluate because other changes in football have occurred along with the use of prophylactic braces that could affect injury rates (e.g., new rule changes, changes in coaching techniques, the use of artificial turf, alterations in footwear, and the naturally occurring fluctuations in incidence of injury from year to year).

An important concern in athletics, other than the efficacy of prophylactic braces as an injury preventing device, is the effect these braces have on athletic performance. Various research studies in this area have shown facilitated performance, impaired performance, and no difference in athletic performance with brace use compared to no brace use.

In addition to the reports of impaired performance and the possibility of preloading, other drawbacks of brace use have been cited. These include high costs to outfit athletes with braces, muscle cramping, problems with player acceptance, and skin rashes due to anchorage of the brace to the skin.

Clearly, the widespread use of knee braces in athletics must be questioned because of the contradictory results regarding injury prevention and effect on performance. Further research needs to be conducted to determine whether braces are doing more good or harm.

Chapter 3

METHODS AND PROCEDURES

This chapter considers the methods and procedures involved in this investigation. The following sections are addressed: selection of subjects, testing instruments, methods of data collection, and analysis of data.

Selection of Subjects

Subjects were 25 volunteers between the ages of 18 and 23 years from the Ithaca College and Cornell University football teams. Subjects were recruited via a telephone recruitment message (Appendix A), and two appointments were scheduled for each subject at his convenience. Each subject completed an informed consent form detailing procedures and purposes of the study (Appendix B) and a knee injury history and brace usage questionnaire (Appendix C). Only subjects classified as having healthy knees were allowed to participate.

Testing Instruments

A Cybex II isokinetic dynamometer with an Isotechnologies Retrofit Package interfaced with an IBM-AT Computer utilizing Isoscan (Version 2.0 Isotechnologies, Inc.) specialized hardware and computer software were used to obtain values of peak torque, rise time, and time to fatigue. An Autolet (Ulster Scientific, Inc.) was used to draw fingertip blood samples, and the YSI Model 27 Industrial Analyzer and YSI 2746 L-Lactate Kit (Yellow

Springs Instrument Co., Inc.) were used to measure blood lactate concentrations. The Wingate anaerobic test was performed on a Monark cycle ergometer (model 850) modified with a Lafayette counter (model 5822) to record pedal revolutions. A Franz metronome (model LM-FB) set the cadence during the warm-up phase of the Wingate test. A Stromgren dual-hinged prophylactic knee brace was worn by subjects during the brace testing condition.

Cybex Tests

Two tests were performed on the Cybex. The first test required each subject to perform eight maximal efforts of complete leg extension and flexion with his dominant leg at 60 deg/s after one maximal and two easy practice efforts. The second test required each subject to maximally extend and flex his dominant leg for 150 s at 120 deg/s after one maximal and two easy practice efforts. Each subject was instructed to continue for 150 s or until he could no longer continue. No encouragement was given during the test. Each subject was stabilized at the lower leg, thigh, pelvis, and chest, and asked to cross his arms over his chest to ensure that cheating or substitution could not occur.

Wingate Anaerobic Test

This test consisted of four phases: a warm-up period, a rest interval, the test, and a cool-down period. As a warm-up, the subjects were instructed to ride an ergometer for 4 min at an intensity to cause the heart rate to reach 130-150 beats/min. A stethoscope was used to monitor heart rate during the 1st minute. Pedal cadence was established by a metronome set at 100 beats/min. For the last 5 s of every minute the subjects were instructed to cycle as fast as possible and then return to the metronome cadence. After the warm-up phase, the subjects were instructed to remain seated for a 2-min rest interval. The test required the subjects to ride as fast as possible while the resistance was progressively increased to a predetermined load within 2-4 s. The Wingate procedure for determining this load was modified as shown in Appendix D. At the moment the final load was reached the test period began and pedal revolutions were recorded every 5 s for a total of 30 s (i.e., six 5-s intervals). As a cool down, the subjects were instructed to continue pedaling at a light load for 2-3 min to minimize the risk of blood pooling and fainting.

Methods of Data Collection

Subjects were asked to report twice to the Ithaca College Physical Therapy Electrophysiology Laboratory for testing. Each subject was tested with a brace during one trial and without a brace during another trial according to random assignment. On each visit, resting and postexercise blood samples were taken and stored in a cooler of ice until subsequent (within 3 hours) analysis for lactic acid. The subjects performed two tests on a Cybex dynamometer and a test of maximal anaerobic power on a Monark cycle ergometer. Data from the two Cybex tests, the Wingate anaerobic test, and lactate concentrations were recorded on individual data sheets (Appendix E). Additionally, subjects who expressed familiarity with a brace were noted.

On each testing day the subjects warmed up by walking on a level treadmill for 3 min at 3 mph and then completed the Cybex tests with a 1-min rest interval between the tests. Peak torque was measured during the first test as the highest quadriceps torque during eight maximal effort knee extensions and flexions at 60 deg/s. Rise time was measured during the first test as the time in seconds from the beginning of the first knee extension to peak torque at 60 deg/s. Time to fatigue was measured during the second test as the time in seconds from peak quadriceps torque to half of peak torque at 120 deg/s.

After the Cybex tests the subjects were instructed to walk or stretch for 3 min before performing the Wingate anaerobic test. Maximal anaerobic power was recorded as the greatest of the power measurements among the six 5-s intervals. Power for each interval was calculated in watts by multiplying 11.765 times the product of the resistance in kiloponds used for each subject during the test and the number of pedal revolutions in each 5-s interval (Lamb, 1984).

Analysis of Data

MANOVA was performed to examine if a statistically significant difference in lactate concentration, maximal anaerobic power, peak torque, rise time, and time to fatigue existed between brace and no brace testing. Three 2 x 2 factorial MANOVAs were performed to examine the effect of subjects' familiarity with a brace on performance, if there was an order effect on performance (i.e., a difference in performance scores that could be attributed to whether the brace was worn during Trial 1 or Trial 2), and if there was a trial effect on overall performance (i.e., a difference in performance scores across trials regardless of brace or no brace condition). In addition, a univariate ANOVA was performed on maximal anaerobic power to examine if a trial effect occurred.

Chapter 4

ANALYSIS OF DATA

The results of this investigation are reported in this chapter, which is divided into sections describing (a) characteristics of subjects, (b) MANOVA for brace effect, (c) MANOVA with familiarity considered, (d) MANOVA with order considered, (e) MANOVA with trial considered, and (f) ANOVA for maximal anaerobic power.

Characteristics of Subjects

The means and standard deviations for age, weight, and height of the 25 football players are given in Table 1. The ages of the athletes ranged from 18 to 23 years. The weights of the athletes ranged from 70.0 to 121.0 kg, and their heights ranged from 1.70 to 1.96 m.

MANOVA for Brace Effect

Table 2 presents the results of MANOVA for brace application upon athletic performance as described by lactate concentration difference, maximal anaerobic power, peak torque, rise time, and time to fatigue. The subjects' raw performance scores for these variables appear in Appendix F. An outlying value for rise time that was found in the data was brought within two standard deviations of the mean value. This had no effect on MANOVA results. No significant difference, $F(5, 20) = 1.111$, $p > .05$, between brace and no brace application on overall performance was found. Therefore, the null hypothesis was not rejected.

Table 1

Characteristics of Subjects

	M	SD
Age (years)	19.60	1.63
Weight (kg)	89.46	12.83
Height (m)	1.82	.06

Table 2

MANOVA Results

	df	*F*
For Brace Effect Only		
Brace	5,20	1.11
With Familiarity Considered		
Brace	5,19	.70
Familiarity	5,19	1.08
Familiarity x Brace	5,19	.57
With Order Considered		
Brace	5,19	2.10
Order	5,19	.04
Brace x Order	5,19	1.84
With Trial Considered		
Trial	5,19	1.84
Order	5,19	.07
Trial x Order	5,19	2.42

MANOVA with Familiarity Considered

Table 2 also presents the results of a 2 x 2 factorial MANOVA that examined the effect of subjects' familiarity with a brace (defined as required seasonal brace use) on performance. No significant interaction of familiarity by brace, $F(5, 19) = .568$, $p > .05$, was found. In addition, no significant difference ($p > .05$) in performance existed between subjects who were familiar with a brace and those who were unfamiliar with a brace. Therefore, the null subhypothesis regarding subjects' familiarity with a brace was not rejected.

MANOVA with Order Considered

A 2 x 2 factorial MANOVA with the order factor considered was conducted to examine if there was a difference in performance between subjects tested first with the brace (Order 1) and those tested first without the brace (Order 2). This removed within group variability from the error term for the F test on brace effect. Both Order 1 and Order 2 followed the same pattern for brace and no brace testing. Therefore, no significant interaction of order by brace, $F(5, 19) = 1.839$, $p > .05$, existed (see Table 2). There was also no significant difference in performance scores between the two groups, Order 1 and Order 2. Therefore, the null subhypothesis regarding an order effect was not rejected.

MANOVA with Trial Considered

A 2 x 2 factorial MANOVA was performed to examine if there was a difference in subjects' performance scores between Trial 1 and Trial 2 (i.e., a learning effect from Trial 1 to Trial 2). No significant interaction of trial by order, $F(5, 19) = 2.42$, $p > .05$, was found (see Table 2). In addition, no significant difference ($p > .05$) in performance existed between Trial 1 and Trial 2. Therefore, the null subhypothesis regarding a learning effect from Trial 1 to Trial 2 was not rejected.

ANOVA for Maximal Anaerobic Power

Typically, univariate ANOVA would not be performed if MANOVA results were not significant. However, the univariate ANOVA for subjects' maximal anaerobic power scores on Trial 1 and Trial 2 was performed to compare the results of this study with a previous study. A trial effect on maximal anaerobic power was observed, indicating that subjects significantly increased, $F(1, 23) = 4.65$, $p < .05$, their power scores from Trial 1 to Trial 2. The interaction of order by trial was not statistically significant, $F(5, 19) = 4.13$, $p > .05$. However, a disordinal pattern was observed for Order 1 and Order 2 subjects' power scores across Trial 1 and Trial 2 (see Figure 1), which indicates that the simple main effects should be considered. Tukey's (a) test for unconfounded means, which is a multiple comparison test that determines which cell means differ significantly from each other

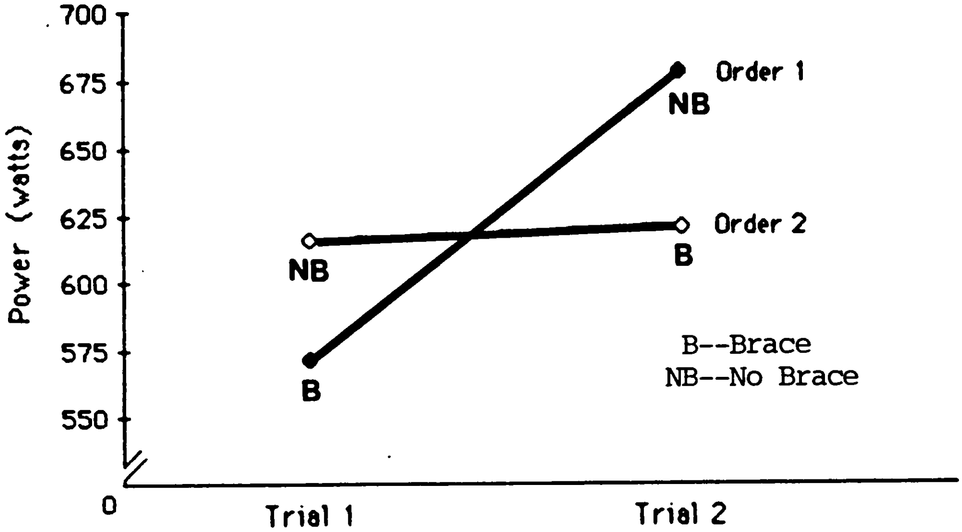

Figure 1. Maximal anaerobic power scores for subjects on each trial.

(Cicchetti, 1972), demonstrated that Order 1 subjects significantly increased their power scores from Trial 1 to Trial 2, whereas, Order 2 subjects did not. Thus, the performance of Order 1 subjects appears to account for the significant trial effect observed.

Summary

No significant difference (p > .05) in overall performance between brace and no brace testing was observed. In addition, subjects' familiarity with a brace and their order of brace and no brace testing during Trial 1 and Trial 2 had no effect on overall performance. Although a significant trial effect was not observed on the combined performance variables (i.e., subjects' performance scores did not increase from Trial 1 to Trial 2), a significant (p < .05) trial effect was observed on maximal anaerobic power. A Tukey test demonstrated that the performance of Order 1 subjects accounted for the significant trial effect observed.

Chapter 5

DISCUSSION OF RESULTS

The number of practice and game days per season that athletes sit out due to knee injury is considerable. Prophylactic knee braces are worn with the intention of preventing knee injury. However, the effectiveness of these braces in preventing knee injury has not been conclusively substantiated. Accordingly, an important concern of coaches and athletes regarding prophylactic braces is the effect they have on athletes' performances. The purpose of this investigation was to examine the effect of a prophylactic knee brace on selected parameters of muscle performance in college football players. MANOVA revealed that overall performance as described by lactate concentration difference, maximal anaerobic power during a Wingate cycle test, and Cybex variables (peak torque, rise time, and time to fatigue) was not significantly different ($\underline{p} > .05$) between brace and no brace conditions. Therefore, the null hypothesis of this study was not rejected.

Hansen's study (1981), in which football players were utilized as subjects, reported results similar to the present study. No significant differences in Cybex measurements of strength, endurance, and power between brace and no brace testing was found. Results from Clover's investigation (cited in Prentice and Toriscelli, 1986) support those of Hansen and the present investigation.

Maximum torque production of male subjects free of knee injury were no different with and without brace application.

In contrast, several investigators have observed negative effects of brace use on these same variables. Knutzen et al. (1984) reported a trend toward reduced torque values of male subjects with surgically repaired knees with brace use when compared to no brace use. Houston and Goemans (1982) also found that peak torque values of male subjects with histories of knee injury during dynamic contractions were significantly lower when subjects wore their prescribed knee braces. In addition, lactate concentration of subjects during a 15-min ergometer ride increased by 41% when a brace was worn, indicating that fatigue occurred earlier with brace use.

It is noteworthy that investigators who reported no effect of brace use on performance utilized male subjects free of knee injury, whereas, the investigators who observed impaired performance with brace use utilized male subjects with previous histories of knee injury. Apparently there is a difference in performance with brace use between noninjured and injured males. This performance difference might be attributed to strength discrepancies in athletes with injured knees compared to athletes with noninjured knees.

Chen (1987) investigated the identical physical variables as the present investigation utilizing female lacrosse players as subjects. Overall performance was observed to be significantly impaired ($p < .05$) when subjects wore a brace. Rise time and time to fatigue were longer, lactate difference higher, and peak torque and peak power were greater during the brace condition compared to the no brace condition. It is difficult to explain why the results of the present investigation oppose Chen's. One possible explanation might be that male subjects free of knee injury are able to overcome the resistance of a brace with better success than females due to differences in strength and training.

Overall performances of subjects who were familiar with brace use and those of subjects who were unfamiliar with brace use were examined because Prentice and Toriscelli (1986) have suggested that prior brace use by athletes may affect their performances when tested with a brace. The present investigation observed that subjects who were familiar with brace use performed no differently than subjects who were unfamiliar with brace use. Houston and Goemans (1982) also observed that subjects' familiarity with their prescribed knee braces did not influence their performance when tested with a brace. The subjects wore their braces during athletic training, competitions, and recreational activities. In spite of this familiarity, subjects performed worse on dynamic leg tests during the brace condition than during the no brace condition.

Overall performances of subjects on Trial 1 and Trial 2 were examined to determine if a learning effect due to repetitive testing occurred (i.e., an increase in power scores from Trial 1 to Trial 2 despite order of brace or no brace testing). MANOVA results showed no indication of a learning effect on the combined performance variables. These results are supported by those of Hansen (1981) in which data from two trials of Cybex tests performed by football players without a brace were not significantly different. However, Chen (1987) reported an indication of a learning effect on the Wingate cycle test. Peak power scores of female lacrosse players on the Wingate test were higher during Trial 2 than they were during Trial 1 regardless of brace or no brace condition.

In the present investigation, a significant trial effect was also found on maximal anaerobic power, indicating that subjects may learn how to perform the Wingate cycle test more efficiently on the second trial. Initially, this effect appeared to be solely accounted for by Order 1 subjects. If indeed a learning effect had occurred, Order 2 subjects should have also increased their power scores from Trial 1 to Trial 2, but they did not. If one assumed that the learning effect did actually occur, the question would then be what negative factor for Order 2 subjects counteracted the expected increase on Trial 2 so that no change was seen in maximal anaerobic power scores. The most obvious factor would be a negative brace effect. This explanation would also be consistent with the results of Order 1 subjects, in that an increase in power scores from

Trial 1 to Trial 2 would be augmented by removing the brace on Trial 2. It appears, then, that there may be a learning effect on the Wingate cycle test coupled with a negative brace effect on maximal anaerobic power. This conclusion is made in spite of MANOVA results that did not demonstrate a significant trial or brace effect for the combined performance variables (i.e., lactate concentration difference, peak torque, rise time, time to fatigue, and maximal anaerobic power).

Summary

The results of this study showed no significant difference in overall performance between brace and no brace use. Various research data support or conflict with the results of the present investigation. The types of subjects utilized in each of the previous research designs could account for the different results observed. Male subjects free of knee injury may be able to overcome the resistance of a brace with better success than females or male subjects with histories of knee injury. In addition, results showed that subjects who are familiar with brace use perform no differently than subjects who are unfamiliar with brace use.

A learning effect on the combined performance variables was not indicated. However, a significant trial effect was observed for subjects on maximal anaerobic power, indicating that subjects may learn how to perform the Wingate cycle test more efficiently on the second trial. At first, it appeared that Order 1 subjects solely accounted for the trial effect observed, however, it is possible that a negative brace effect on maximal anaerobic power counteracted the learning effect on the Wingate cycle test for Order 2 subjects, resulting in no change in maximal anaerobic power scores from Trial 1 to Trial 2.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study examined the effect of a Stromgren prophylactic knee brace on muscle performance as described by lactate concentration difference, maximal anaerobic power, peak torque, rise time, and time to fatigue. The subjects (N = 25) were football players aged 18 to 23 years from Ithaca College and Cornell University.

Each subject performed the identical tests during one trial with a brace and another trial without a brace. The subjects' sequence of brace and no brace trials was randomized. Each subject performed two tests on a Cybex II isokinetic dynamometer and the Wingate anaerobic cycle test. In addition, resting and postexercise blood samples were obtained from each subject on both trials. Subjects who were familiar with brace use were noted.

MANOVA revealed no significant difference (p > .05) in overall performance between brace and no brace trials. A 2 x 2 factorial MANOVA showed no significant interaction of familiarity by brace, and no significant difference in performance between subjects who were familiar with brace use and those who were unfamiliar with brace use. A second 2 x 2 factorial MANOVA showed no significant interaction of order by brace and no significant difference in overall performance between Order 1 and Order 2 subjects. In addition, no significant trial by order interaction was found, and no significant difference in overall performance between Trial 1 and Trial 2 existed. A univariate ANOVA on maximal anaerobic power demonstrated a significant (p < .05) trial effect, indicating that subjects may learn how to perform the Wingate cycle test more efficiently on the second trial. However, a Tukey test revealed that there was a significant trial effect for Order 1 subjects but not for Order 2 subjects. It is possible that a negative brace effect on maximal anaerobic power counteracted the learning effect on the Wingate cycle test for Order 2 subjects, although MANOVA results did not demonstrate a significant brace effect on overall performance.

Conclusions

The results of this study yield the following conclusions regarding the effect of brace use on muscle performance:

1. There is no significant effect of brace use by male football players free of knee injury on muscle performance as described by lactate concentration difference, maximal anaerobic power, peak torque, rise time, and time to fatigue.

2. Subjects' familiarity with a brace does not influence performance.

3. A learning effect coupled with a negative brace effect on the Wingate cycle test may occur.

Recommendations

The following recommendations for further study were made after the completion of this investigation:

1. A study should be conducted that examines the possibility of a learning effect on the Wingate cycle test.

2. Once a reliable schedule of measurement has been established for the Wingate cycle test, a study should be conducted to isolate the effect of a brace on maximal anaerobic power.

3. A study similar to the present one should be conducted that utilizes bilateral application of braces.

4. A study similar to the present one should be conducted utilizing different prophylactic braces.

5. A study should be conducted that examines sport specific skills with unilateral and bilateral brace application.

Appendix A

TELEPHONE RECRUITMENT MESSAGE

I was the student athletic trainer for the Cornell University freshman football team last semester. I am conducting an investigation to examine the effect of a protective knee brace on leg muscle performance. May I continue to see whether or not you are interested?

You will be required to visit the Ithaca College Physical Therapy Laboratory twice. Approximately 1 hour is needed for each visit. You will be required to fill out an informed consent form and a knee injury history and brace usage questionnaire on the first visit.

The investigation consists of performing the identical physical tasks on both visits. During only one visit you will wear a knee brace. The physical tasks consist of walking on a treadmill for 3 min, performing two tests on a Cybex machine, and performing a bicycle test. You will also be required to allow two blood samples to be drawn from your finger tip.

Would you be willing to participate? Which of the following times is most convenient for you?

Appendix B

INFORMED CONSENT FORM

1. Purpose of the Study. To examine the effect of a protective knee brace on muscle performance (e.g., muscle strength, endurance, and power).

2. Benefits. This study will attempt to provide information about the influences of a protective knee brace on leg muscle performance. It is hoped that the results of this study will provide useful information to encourage or discourage the further use of protective knee braces in physical activity.

3. Method. You will be asked to fill out a knee injury history and brace usage questionnaire (see attached). You will be asked to visit the Ithaca College Physical Therapy Laboratory two times and repeat the following procedures, once wearing a knee brace and once without a knee brace:
   (a) Allow two small blood samples to be taken by the finger prick technique.
   (b) Walk on a level treadmill for 3 minutes as a warm-up.
   (c) Perform two tests on a Cybex II dynamometer. The first test involves maximally extending and flexing the knee joint 8 times. The second test involves maximally extending and flexing the knee joint until exhaustion.
   (d) Ride a bicycle ergometer for 4 minutes as a warm-up, then ride for 30 seconds until exhaustion.

4. Will this hurt? No lasting physical or psychological pain will result from this experiment. Subjects may experience muscle ache as fatigue approaches at the end of exercise, delayed muscle soreness, and minor discomfort from the finger prick technique used to obtain blood samples. This discomfort is minimal, and delayed muscle soreness will disappear within 48-72 hours.

5. Need more information? Additional information can be obtained from either Cindi Gold (277-5723) or Dr. Gary Sforzo (274-3359). All questions are welcomed and will be answered.

Appendix B (continued)

6. Withdrawal from the study. Participation is voluntary You are free to withdraw your consent and discontinue at any time without prejudice of any kind.

7. Will the data be maintained in confidence? All data will be confidential. Once data are collected, names of subjects will be discarded and replaced by subject number (e.g., Subject 1). Data will be analyzed by group, not by individual subject.

8. I have read the above, and I understand its contents.

   I agree to participate in the study. I acknowledge

   I am 18 years of age or older.

____________________ ____________________

Signature Date

Appendix C

KNEE INJURY HISTORY AND BRACE USAGE QUESTIONNAIRE

Please Print

Name: ______________________________

Date of birth: ____________________

Home address: ____

Phone: ________________

Do you have any systemic disease? Y N

If yes, please specify: ___________________________________

Have you ever received treatment to the knee joint? Y N

If yes, please write down the reason: __________________

____

When: ______________________________

Have you ever had a knee injury before? Y N

If yes, please describe: ________________________________

When: ______________________________

Do you presently have a muscle injury? Y N

If yes, please specify: _________________________________

Do you have muscle pain at rest? Y N

If yes, please specify: _________________________________

Appendix C (continued)

Do you exercise regularly? Y N

If yes, please list type and intensity:

Do you feel any muscle pain upon exertion? Y N

If yes, please specify: ______________________________

Do you feel any knee joint pain after exercise? Y N

If yes, please describe: ______________________________

Have you ever worn a knee brace before? Y N

If yes, please give the name of the brace:

When did you wear it?

How long did you wear it?

Why did you wear it?

Do you currently wear a knee brace? Y N

If yes, please give the name of the brace:

When do you wear it?

How long have you been wearing it?

Why do you wear it?

Appendix D

PROCEDURE TO DETERMINE RESISTANCE FOR WINGATE TEST

Subject's Weight (kg)	Resistance Used (kp)
>91	7
82 - 90	6
68 - 81	5
59 - 67	4

Appendix E

INDIVIDUAL DATA SHEET

Name:	ID number:
Weight:	Age:
Height:	Resistance Used:

<u>WINGATE TEST RESULTS</u>

	Number of Revolutions		Watts = kp x revs. x 11.765		
	Brace	No Brace		Brace	No Brace
5 s			Power:		
10 s			Power:		
15 s			Power:		
20 s			Power:		
25 s			Power:		
30 s			Power:		

<u>CYBEX TEST RESULTS</u>	Brace	No Brace
Peak Torque:		
Rise Time:		
Time to Fatigue:		

<u>LACTATE DATA</u>

Pretest:

Posttest:

Appendix F

RAW PERFORMANCE SCORES OF SUBJECTS

Subject/ Condition	Power (watts)	Torque (ftlbs)	Rise (sec)	Fatigue (sec)	LaPre (mM)	LaPost (mM)
1 Brace	776.5	212.0	6.4	43.6	2.3	11.1
No Brace	705.9	202.0	6.4	28.6	2.5	9.4
2 Brace	741.2	138.5	0.3	59.6	1.0	9.3
No Brace	741.2	154.7	0.3	94.5	0.8	8.7
3 Brace	529.4	140.0	7.2	90.9	1.2	12.0
No Brace	647.1	136.5	3.8	98.4	1.3	12.3
4 Brace	494.1	202.0	3.1	91.1	2.6	15.4
No Brace	658.8	196.0	12.8	102.2	2.8	12.3
5 Brace	635.3	220.0	6.5	58.0	1.6	11.3
No Brace	776.5	208.2	12.9	40.3	2.0	10.8
6 Brace	658.8	200.0	3.7	46.5	1.1	8.2
No Brace	411.8	234.7	3.4	49.6	1.8	6.0
7 Brace	658.8	170.6	0.3	48.6	1.5	11.9
No Brace	494.1	191.8	3.1	41.2	1.8	13.9
8 Brace	529.4	150.0	4.0	40.0	1.0	8.1
No Brace	588.3	150.9	7.2	37.4	1.4	10.4
9 Brace	647.1	198.0	20.6	49.8	2.9	11.1
No Brace	588.3	182.4	7.6	69.1	1.7	14.2
10 Brace	494.1	184.6	0.8	26.4	1.3	9.5
No Brace	741.2	206.0	0.2	25.3	0.8	7.6
11 Brace	529.4	198.1	2.8	29.4	0.8	10.4
No Brace	588.3	167.3	6.0	47.8	1.7	10.6
12 Brace	576.5	221.2	0.3	37.8	1.6	12.7
No Brace	494.1	240.4	0.4	45.1	1.1	11.5
13 Brace	647.1	158.8	6.6	37.2	1.3	12.9
No Brace	705.9	156.9	9.4	52.9	1.7	14.6
14 Brace	529.4	164.7	6.9	47.7	2.5	14.6
No Brace	647.1	167.3	7.9	48.2	1.9	14.2

(table continues)

Subject/ Condition	Power (watts)	Torque (ftlbs)	Rise (sec)	Fatigue (sec)	LaPre (mM)	LaPost (mM)
15 Brace	494.1	188.5	0.4	26.8	1.3	8.2
No Brace	576.5	190.0	7.0	26.8	0.9	9.1
16 Brace	705.9	192.3	0.2	27.5	1.7	11.3
No Brace	705.9	184.6	3.0	48.0	1.8	9.3
17 Brace	588.3	192.2	3.7	55.2	2.8	13.8
No Brace	647.1	154.9	15.3	56.2	1.6	13.9
18 Brace	423.5	233.3	6.0	34.6	1.5	7.9
No Brace	705.9	184.0	12.7	50.3	1.9	9.5
19 Brace	658.8	211.8	6.4	42.7	2.2	8.4
No Brace	494.1	202.0	0.3	18.2	2.2	7.7
20 Brace	635.3	139.2	4.0	37.7	1.7	14.0
No Brace	705.9	180.0	19.4	32.8	1.8	12.1
21 Brace	705.9	176.4	3.0	29.6	2.3	11.0
No Brace	635.3	190.0	18.4	47.5	2.1	11.3
22 Brace	705.9	126.4	0.1	65.4	1.6	9.2
No Brace	705.9	143.4	0.2	64.2	1.8	9.8
23 Brace	411.8	177.8	0.3	59.0	2.3	12.5
No Brace	658.8	165.4	5.4	71.0	2.4	11.5
24 Brace	576.5	187.0	2.7	36.2	2.1	12.7
No Brace	741.2	219.2	3.6	47.0	2.6	11.4
25 Brace	705.9	186.5	8.5	54.8	2.2	12.7
No Brace	705.9	190.7	0.2	39.6	2.8	11.8
Brace *M*	602.4	182.8	4.2	47.0	1.8	11.2
SD	98.8	28.5	4.4	17.3	.6	2.1
No Brace *M*	642.8	184.0	6.7	51.3	1.8	10.9
SD	93.2	26.9	5.8	21.8	.6	2.2

Note. Power = maximal anaerobic power, Torque = peak torque, Fatigue = time to fatigue, LaPre = blood lactate concentration at rest, LaPost = blood lactate concentration after exercise, ftlbs = foot pounds, and mM = millimoles.

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